the highest was 77°, at Bonair on the 9th, and the lowest, zero, at Hot Springs on the 31st. The average precipitation was 2.61, or 0.53 below normal; the greatest monthly amount, 4.33, occurred at Bigstone Gap, and the least, 1.62, at Stanardsville.

Winter crops made quite favorable progress throughout the month. Thus far no evidences of winter killing have developed. There is very little complaint of damage from hessian fly. The early seeding is generally in fine condition of growth and vigor, while the late seeding is somewhat backward. Considerable spring plowing was done during the latter part of the month in portions of the valley sections.—*E. A. Evans.*

Washington.—The mean temperature was 33.1°, or slightly above normal; the highest was 59°, at Walla Walla on the 12th, and the lowest, 17° below zero, at Republic on the 9th. The average precipitation was 4 56, or 0.37 below normal; the greatest monthly amount, 13.78, occurred at Neah Bay, and the least, 0.84, at Pasco.

Considerable snow fell during the forepart of the month, which melted during the latter part.—*G. N. Salisbury.*

West Virginia.—The mean temperature was 33.6°, or 1.2° above normal; the highest was 69°, at Green Sulphur Springs on the 9th, and the lowest, 4° below zero, at Dayton on the 20th. The average precipitation was 2.41, or 0.52 below normal; the greatest monthly amount, 3.87, occurred at Beverly, and the least, 1.18, at Parkersburg.

The weather has been dry and rather mild during the month, but the almost daily freezing and thawing, with practically no snow protection, has been unfavorable for wheat, rye, and grass.—*E. C. Vose*

Wisconsin.—The mean temperature was 17.8°, or 3.1° above normal; the highest was 59°, at Port Washington on the 19th, and the lowest, 31° below zero, at Grantsburg and Hayward on the 2d. The average precipitation was 0.77, or 0.69 below normal; the greatest monthly amount, 1.70, occurred at Port Washington, and the least, 0.10, at Bayfield.—*W. M. Wilson.*

Wyoming.—The mean temperature was 24.7°, or 2.4° above normal; the highest was 65°, at Cody on the 18th, and the lowest, 44° below zero, at Daniel on the 1st. The average precipitation was 0.26, or 0.39 below normal; the greatest monthly amount, 2.28, occurred at Fort Yellowstone, while none fell at several stations.—*W. S. Palmer.*

Cuba.—The mean temperature was 70.5°; the highest was 91°, at San Cayetano on the 2d, Los Canos (Guantanamo) on the 3d and 16th, and Soledad (Guantanamo) on the 2d and 4th, and the lowest, 38°, at Rosario (Aguacate) on the 27th. The average precipitation was 1.52; the greatest monthly amount, 8.44, occurred at Havana, and the least, 0.22, at Puerto Principe.

The weather was ideal for harvesting and grinding the cane crop, but lack of rain and the prevalence of brisk winds proved injurious to the tobacco.—*M. W. Hayes.*

Porto Rico.—The mean temperature was 74.1°, or 0.7° above normal; the highest was 96°, at Cayey on the 19th, and the lowest, 50°, at Comerio on the 12th. The average precipitation was 5.09, or 0.46 below normal; the greatest monthly amount, 14.20, occurred at Coamo, and the least, 2.19, at Mayagüez.

Sugar making is general and the weather very favorable. Cane is maturing nicely; yield of the crop is an average, but not as good as anticipated. The new crop of cane is doing well and some still being planted. The new crop of tobacco is doing well; the old crop is being cut; yield is below an average, but the quality is good. Coffee trees are blooming well and a good crop is promised. Small crops, such as beans, lettuce, corn, cucumbers, cabbage, carrots, sweet potatoes, squashes, lernes, okra, and cazava, are being gathered. Some new crops are being planted. Rain is needed over the extreme western districts, where the drought continues.—*Joseph L. Cline.*

SPECIAL CONTRIBUTIONS.

THE RELATION OF RAINFALL TO MOUNTAINS.

By W. H. ALEXANDER, Observer Weather Bureau, dated January 18, 1901.

The object of the present communication is to enable the reader to arrive at a clear understanding as to how and to what extent hills and mountains influence the rainfall of a country. To this end attention is invited to a brief summary of well established facts and principles relative to temperature, evaporation, and condensation.

The water contained in any vessel, although it appears to be one mass, is in reality made up of a vast number of minute masses called molecules of water, separate and distinct from each other. Although no one has ever seen these molecules, yet no student of science can doubt their existence any more than he doubts the existence of individual grains of sand in a block of sandstone. It is confidently believed that if a person were endowed with supernatural sight, he could see these countless molecules. Most likely he would be greatly astonished at the large distances separating them and at the rapid and ceaseless motion of these minute bodies among themselves. This inter-molecular motion gives us the phenomenon of heat and the violence of the motion determines the temperature of the body; if they move slowly, the temperature is low; if rapidly, the temperature is high. The amount of heat within a body must depend, not only on the rate of molecular motion, but on the number of the molecules and their size or mass; the amount of heat in a body is the sum total of all the molecular energy within the body. The temperature does not mean the amount of heat, because the body may have a high temperature and very little heat, or a low temperature and a large amount of heat. That heat which a body contains that does not raise its temperature is called latent heat. The amount of heat that it is necessary to give a body in order to raise the temperature of a unit mass by one degree is called the specific heat.

Suppose that in some way the temperature is lowered and molecular motion overcome until finally the molecules cease their struggle and come to rest; the body is now without heat, its temperature is said to be that of absolute zero and the body has contracted in volume to its smallest possible size. Gases, like the air, contract so regularly that by measuring their volumes at temperatures successively lower and lower, it has been calculated that they would have no volume, or one inappreciably minute, at a temperature of about —460° on the Fahrenheit scale, or —273° on the centigrade scale, which, therefore, corresponds with the absolute zero of temperature. If we should put the zero of our thermometer at this point on the scale and count from that point upward, we should have what are called absolute temperatures; thus, the temperature of freezing water is 273° C.; on the absolute scale, or 460° F. A glass of water that has a temperature of 70° on the ordinary Fahrenheit scale, would have one of 530° on the absolute Fahrenheit scale.

Again, as heat is the energy of the rapidly moving molecules, the superhuman observer would see them striking against the sides of the vessel containing the liquid and pounding each other incessantly, thereby producing a pressure against the sides of the vessel; but at the upper surface, the so-called free surface of the liquid, there would seem to be a battle between the molecules of water below and those of the air above. The gaseous molecules are pounding down upon the water, the aqueous molecules are striking upward from below. There is a boundary surface between the two at which a majority of the molecules seem to rebound back into their own element, but occasionally a molecule of water shoots far into the region of air and more rarely one of air shoots into the water. These become, as it were, lawless wanderers in the enemy's country; they are captives that will probably never return to the mass from which they are separated. This breaking away of the molecules of water escaping into the space above is called evaporation. This free molecule is now called water vapor, although no change has occurred in its real nature. The rate at which evaporation takes place depends upon the extent of the evaporating surface as well as on the pressure exerted by the exterior gas upon that surface and on the temperature, not only of the evaporating liquid, but of the gas into which the evaporation takes place. The relation between extent of surface and evaporation is evidently one of direct proportionality. So essential is an abundant evaporation to life upon this earth that three-fourths of the surface of the globe must be devoted to it; but, of course, the evaporation from the salt water ocean is much less vigorous than from surfaces of fresh water.

A hot body evaporates more rapidly than a cold one, because in the hot body the velocities of the molecules are larger and their power to break away and free themselves is greatly augmented without any increase whatever in the restraining power. Moreover, if the atmosphere is also hot, then, its molecules also have greater velocities and are, on the average farther apart, so that there is greater room and opportunity for the passage of the molecules of vapor between them. However, the influence of the atmosphere upon evaporation is purely mechanical, and, in fact, preventive; it simply retards the diffusion. The law on this point is that the rate of evaporation increases nearly in proportion as the barometric pressure diminishes. Air currents are very essential, since they bring about a rapid and thorough distribution of aqueous vapor, which, without such air, would require a very long time to work its way to distant places. If there were no air whatever around a drop of water it would evaporate most freely and rapidly and the space within a given distance, say a radius of one foot, would become saturated with vapor much quicker than if air were present, although strange to say, the actual quantity of vapor evaporated into this saturated space would be, as far as we can measure, precisely the same as if the air were present.

In studying mixtures of gases and vapors, it is important to bear in mind that each gas composing the mixture endeavors to adjust itself to what is called a condition of equilibrium, just as if it were all alone in that space. Hence, it follows that in a mixture of gases the lighter gas does not rise to the top and the dense one sink to the bottom, as a permanent condition of stability, but, although they may temporarily do this, yet, after a sufficient time, we shall find that they have mutually interpenetrated each other and are diffused uniformly throughout the whole space. In fact, one may make a striking experiment, to quote from Watson's Text-book of Physics, London, 1899, pages 166–177:

If two equal bottles, one containing hydrogen and the other carbonic acid gas, are placed mouth to mouth, the bottle containing the hydrogen being on the top, then, after a certain time, it will be found that half of the hydrogen has traveled down into the lower bottle and half of the carbonic acid gas has ascended into the upper bottle, and this in spite of the fact that the density of the carbonic acid gas is 22 times as great as that of the hydrogen.

To illustrate further, suppose that in a cubic foot of air the barometer stands at 30 inches; this pressure is made up of two parts, that which is due to the elastic pressure of the dry air and that which is due to the elastic pressure of the aqueous vapor contained therein. Suppose, now, we raise the temperature of the air and allow moisture to evaporate into the atmosphere and diffuse uniformly until the air, or more properly the space, is saturated, our cubic foot will contain more moisture than before, and if the pressure remain at 30 inches it must therefore contain less air. In a saturated space the amount of moisture depends upon the temperature of the space and not on the barometric pressure, at least for all ordinary cases. It is true we often speak of the air as if it had a capacity for vapor, but in fact it has no power whatever to hold vapor.

Careful experiment has shown that a cubic foot of space, when saturated with moisture, may contain 0.48 grain of aqueous vapor and no more, when the temperature is 0° F. and the barometric pressure within that space will be 0.038 inches unless some other gas is present to increase the pressure. At 100° F., the cubic foot may contain 19.77 grain and the pressure will be 1.916 inches; but if the air is also present to such an extent that its pressure is 28.084 inches, then the total pressure will be 30 inches and the weight of the dry air itself will be 467.77 grains, while the total weight of the vapor and the air in the saturated space will be 485.54 grains. It does not follow that when the air becomes saturated the evaporation ceases; on the contrary, the more proper statement is that at this time the number of molecules that are evaporated from the liquid is exactly equal to the number that return to the liquid, so that the captures on both sides are equal in number.

To show more fully the relations between temperature and moisture in the free atmosphere, attention is invited to the following table [corrected by the Editor to agree with the newest edition of the Weather Bureau psychrometric tables]:

Pressure and weight of vapor and air in a cubic foot of atmosphere at a pressure of 30 *inches when saturated at the respective temperatures.*

Temperature.	Vapor pressure.	Air pressure.	Vapor weight.	Dry air weight.	Saturated air weight.
° *F.*	*Inches.*	*Inches.*	*Grs. per cu. ft*	*Grs. per cu. ft.*	*Grs. per cu. ft.*
0	0.038	29.962	0.48	605.32	605.80
+10	0.063	29.937	0.78	591.93	592.71
20	0.103	29.897	1.24	578.79	580.03
30	0.164	29.836	1.94	565.79	567.73
40	0.247	29.753	2.85	552.89	555.74
50	0.360	29.640	4.08	539.93	544.01
60	0.517	29.483	5.74	526.75	532.49
70	0.732	29.268	7.98	512.98	520.96
80	1.022	28.978	10.93	498.48	509.41
90	1.408	28.592	14.79	482.85	497.64
+100	1.916	28.084	19.77	467.77	485.54

In this table the second and third columns give us the height of the barometer when, in a saturated atmosphere, the mercurial column is sustained only by the pressure of the aqueous vapor or the dry air, respectively. The third column gives the actual weight in grains of the vapor, and the fourth gives the weight of the air in a cubic foot of space saturated at the given temperatures and total pressure of 30 inches. This is the capacity of space, or, if you will, of air, for aqueous vapor, and it increases very rapidly with rising temperature. The rate of rise is only 0.3 grain between zero and + 10°, but it is 5 grains between 90° and 100° F. The last column shows the combined weight of air and vapor in the cubic foot of space when the air is saturated, and we see at once that at high temperatures saturated air weighs less or is much lighter than at low temperatures. The inverse relation is shown in the fourth column, namely, that the higher the temperature so much the less is the quantity of air as distinguished from vapor.

The above figures relate to what is called absolute humidity of saturated air. But if we compare the actual amount present in air that is not fully saturated with what it would be if saturated, we obtain an idea of the relative condition. We may, for instance, say that saturated air has 100 per cent, or all that it can possibly hold at that temperature. If now it has only half that amount, we say that its relative humidity is 50 per cent, or, in general, we obtain the relative humidity by dividing the amount actually present by the amount that is possible in the case of saturation.

There is another method of considering the moisture in the air, namely, we may merely state the temperature to which the air must be cooled in order to produce a slight deposition of dew. This temperature we call the *dew-point of the air.* When air is cooled to its dew-point, it thereby becomes saturated.

To illustrate, when the barometer stands at 30 inches and the air has a temperature of 80° F., I draw a cubic foot of air into a glass globe, apply some drying chemicals which absorb absolutely all the moisture and find that the chemical has increased in weight by 7.99 grains. This represents the weight of the aqueous vapor, or the absolute humidity of the original air. However, from the above table it is seen that it is possible for a cubic foot of air at 80° F. to contain 10.93 grains; hence, by dividing the actual amount, 7.99, by the possible amount 10.93, I obtain for the relative humidity 73 per cent. On the other hand, suppose that without changing the actual amount of vapor in the air I cool down some of the original moist air from 80° F. to 70° F. The above table shows that at 70° F. our 7.99 grains would be sufficient to saturate a cubic foot of air. Hence the air has now reached the dew-point, and the moment the temperature falls below this point condensation of the vapor will begin and will continue so long as the temperature continues to fall. When the temperature has reached 60° F. 2.24 grains of vapor will have been condensed from each original foot of air.

This condensed vapor will appear either in the form of fog. snow, rain, or dew, depending upon other conditions. Condensation is essentially the rushing together of the surplus molecules of aqueous vapor, forming small drops of water or crystals of ice, which become visible as fog or cloud. The tendency of these minute drops is to fall to the ground, but the upward air currents are generally quite sufficient to sustain them until the drops grow to a larger size, when they are precipitated as rain. When the condensation is very rapid the upward currents are also rapid and the raindrops are likely to be large. Of course, snow is formed only when the temperature of condensation, namely, the dew-point, is below freezing.

Precipitation, therefore, depends upon a falling temperature, and the primary question is how may this be brought about. The most common and effective ways and in the order of increasing importance are: (1) cooling by contact with cooler bodies; (2) mixture with air of lower temperature; (3) loss of heat by radiation; (4) loss of temperature by the utilization of heat in work.

1. The direct contact of warm, moist air with a cold surface, it does not matter whether it be a glass containing cold water or a mountain covered with snow, must result in giving up heat to the cold object, which thereby becomes warmer. Now, the quantity of heat that can be taken up by a cold mountain side is very slight. A little dew may be formed on the rocks, but this represents the extent of its power to condense moisture out of the air.

2. When equal parts of cold and warm air are mixed together, both being saturated, a very slight cloud or haze is formed, due to the fact that the saturated warm air contains a little more moisture than was necessary to saturate the mixture, but this slight haze is the extent of the precipitation that can be formed in this way.

3. When the air is nearly saturated in the daytime, it is apt to cool below its dew-point during the following nighttime; there is thus formed a thin layer of fog near the surface of the earth, or of stratus cloud a few yards above the surface, or perhaps alto-stratus a few thousand feet above that. In either case, the lower side of the fog or cloud receives heat from the earth, while it is only the upper side that cools by radiation into space. During long nights this cooling may produce a deep layer of fog, or a thick layer of cloud, and from the upper surface of these there may fall a light, drizzling rain; but this is the maximum extent of the influence of radiation.

4. The conversion of the molecular energy that we call heat into the movement of large masses that we call work is the most important method of cooling. Whenever a given volume of air flows into a region where the barometric pressure is less, it expands and in this expansion must push aside the air immediately surrounding it. This is the work that is done, and it is exactly equivalent to the amount of heat energy that is consumed. Thus, the steam in a boiler flows into the cylinder and pushes the piston ahead, by doing so it does work and cools off. When the safety valve of the boiler is open, the steam rushes out with great force, expands greatly in volume and cools. In fact, it falls from the temperature within the boiler to the temperature of the open air. When this process takes place quickly and no other heat comes in to disturb the conditions, this is called adiabatic expansion or adiabatic cooling. Whenever a mass of moist air is pushed by the wind over a hill or mountain it expands as it ascends because the pressure diminishes with altitude, and its temperature may easily be reduced below the dew-point, so that by cooling it forms a cloud and by still further cooling may form rain. Ascending air, under the ordinary barometric conditions, must cool at the rate of 1° C. for about 100 meters of ascent, or 1° F. for 183 feet of ascent. Thus, suppose our cubic foot of air at 80° F. to be lifted 1830 feet it would then have cooled to a temperature of 70° F. and be saturated; should it be carried still higher condensation must occur. It is evident that the height to which a body of air must be raised before condensation begins depends upon both the temperature and the humidity of the air at sea level. Hence in regions of high humidity comparatively low mountains may be important agents in bringing about rainfall, whereas in regions of low humidity very high mountains may have little influence. There are mountains which rise to such a height that the air about their summits has a temperature of freezing or less, so that the mountains have a crown of perpetual snow.

The office of mountains is to force the warm moist surface wind into higher regions whereby it is expanded and cooled, and in this way only do they bring about condensation and precipitation. A single peak, even if very high, may not be very effective, as the air currents may pass around it instead of over it, and will merely form clouds in the region of slightly diminished pressure and upward rising currents on the leeward side of the peak. But in the case of a mountain range the whole mass of air driven by the wind must pass over and must, therefore, rise to higher regions in order to do so. The mistake should not be made of supposing that the mountain "acts as a condenser" in the same sense that a blade of grass when chilled by radiation, cools the air in contact with it and accumulates dew. It is evident that if a mountain did act in this way the moisture would be deposited on it in the same manner as dew or frost is deposited on the grass, or on the cool exterior of a glassful of ice water, and the precipitation would not appear as a cloud or as rain. In general, the mountains act merely as obstacles to the currents of air. A mountain may be very effective in the formation of clouds without having much influence on the rainfall. The region or side of the mountain upon which the rain will fall depends almost entirely on the direction from which the moist wind comes. In some cases the wind deflected upward by the mountain may continue rising for a short distance beyond the mountain, so that the rain may fall to the leeward rather than on the mountain itself.

CLIMATE AND CORN.

By H. B. Wren, U. S. Weather Bureau.

The weather exerts a tacit, though relentless, tyranny over the labor and the thought of the agriculturist. The probable influences of the present and prospective weather upon the growing crops are seldom absent from his mind. But science teaches that climate is rhythmic, not capricious. Laplace has shown that the mean temperature of the mass of the earth can not have changed in any appreciable measure during the entire period of astronomical calculation and that while the planetary movements remain as at present no such change can occur. "Astronomical permanency," he says, "implies an absolute fixedness of the quantity of heat for